GENERAL PHYSICS 2 PHY102

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Course webpage elearning.fuoye.edu.ng

DEPARTMENT OF PHYSICS

SECOND SEMESTER 2015/2016 ACADEMIC SESSION

PHY 102 GENERAL PHYSICS II

week	Lecturer	Topics	Test
1			
2	**Dr. E.A. Odo**	Electrostatics; conservation law of electric charges, electrons and electrostatics, Coulomb's law	
3	**Prof Anthony Mukolu**	Electric field and forces, Electric field line, electric dipoles charged particles in an electric field	
4	**Dr. Olusayo Olubosede**	Charge and electric flux, Gauss's law and its applications Electric potential	
5	**Dr. Hammed Sakiru**	Electric potential due to a single charge, electric potential due to a dipole, electric potential due to continuous charge distribution equipotential surfaces.	
6	**Dr. O.O. Oketayo**	Conductors and currents: Electric current, resistors and resistance, electric power	**Test 1**
7	**Dr. Igboama**	Capacitors in series and parallel energy storage in capacitors and electric field energy	
8	**Mr O.J. Oluwadare**	Gauss's law in dielectrics. Magnetism: magnetic field, magnetic force on a current carry conductor	
9	**Dr. Ibiyemi Abideen**	Ampere's law, Bio-Savart law, electromagnetic induction	
10	**Mr. Oladipo Abe**	Inductance, self-inductance, mutual inductance	
11	**Mr. Abass Faremi**	Maxwell's equations; electromagnetic oscillations and waves; Applications.	**Test 2**

Miss Chima Odoh and Mr. Oke Aduragbemi will act as Tutorial Instructor

Lecture Time: Tuesday 12- 2pm
Wednesday 11-12pm

My expectations of you …

1. … that if you come to lectures, then you will engage with what is happening
2. … that you read M&I daily (before and after lectures)
3. … that you do what I ask you to do
4. … that you will not copy another student's work, but work together, where appropriate.
   (Collaboration becomes copying when both parties are not gaining positive learning from the activity.)
5. … spend enough time at home working on what you need to …

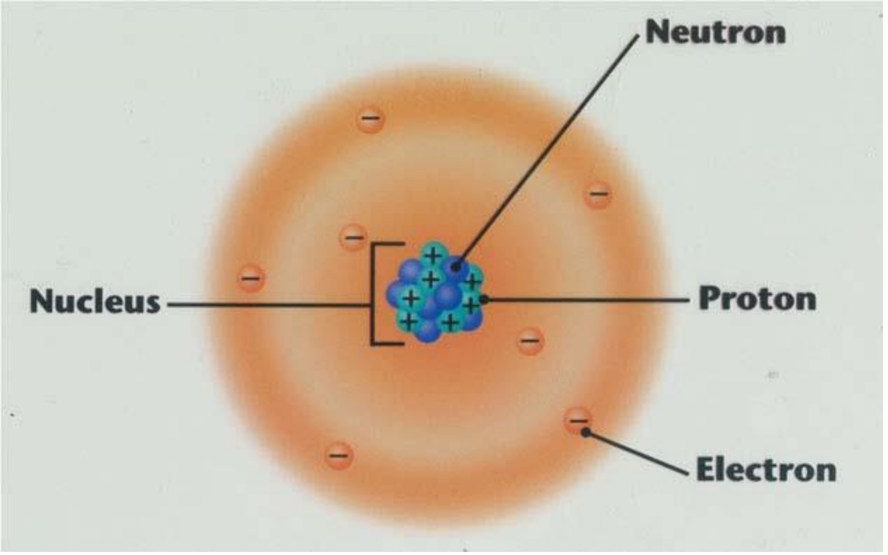
… what you can expect from me …

1. … the best course that I can deliver
2. … a reasonable and appropriate homework load.
3. … no mercy in the face of plagiarism
4. … an <u>open door</u> policy

Electrostatics

There are two kinds of electric charges, which were given the names positive and negative

- The charge on an atom is determined by the subatomic particles that make it up.

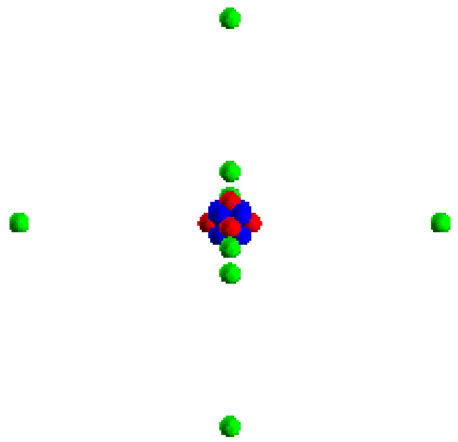


Proton- has a positive charge and is located in the nucleus.

Neutron- has no charge (is neutral) and is also located in the nucleus as it fills in the spaces between the protons.

Electron- has a negative charge and is located outside of the nucleus in an electron cloud around the atom.

Particle charges:

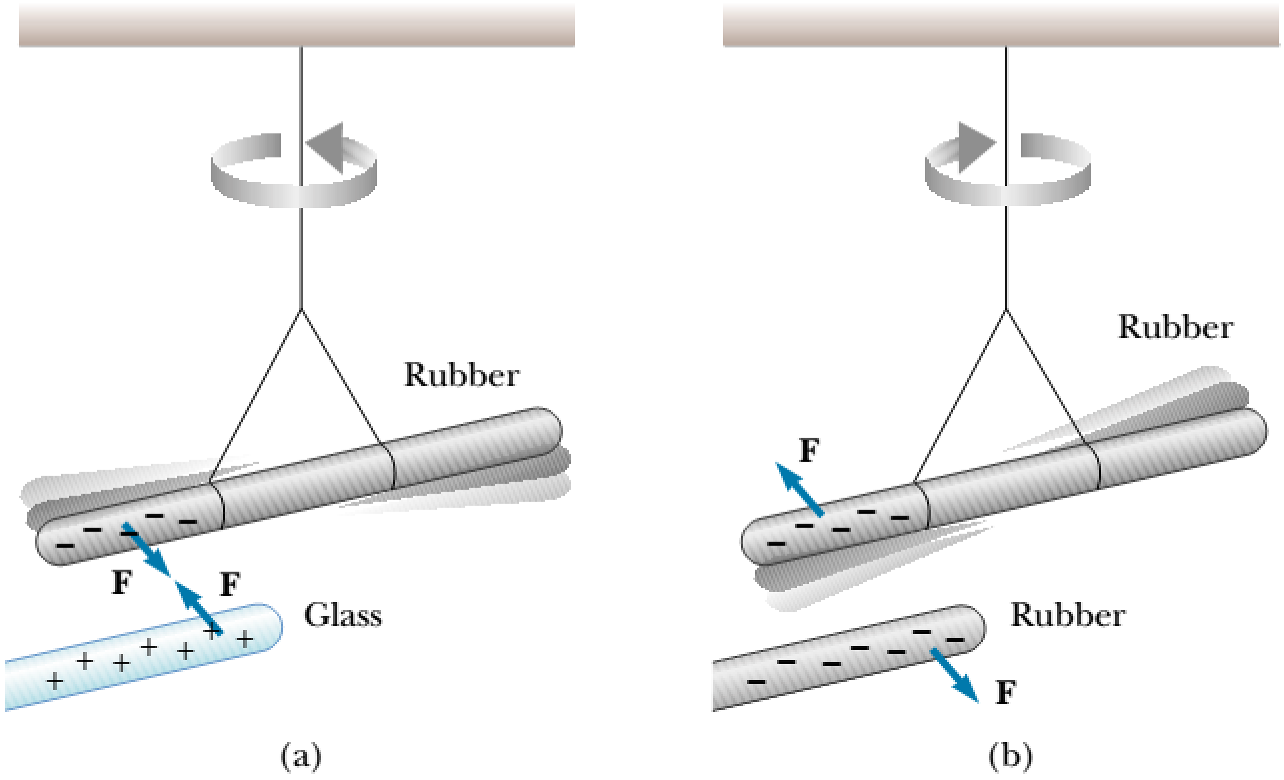


Because atoms have the same amount of protons and electrons they are electrically neutral. (Nitrogen has an atomic number of 7- 7 protons orbited by 7 electrons).

- Electrons and protons have the same magnitude of charge (elementary charge, *e*).
- Electron (-*e*): -1.60×10^{-19} C
- Proton (+*e*): $+1.60 \times 10^{-19}$ C
- This is why electrons are forced to orbit around the nucleus.
- Electrostatic Forces hold atoms together.
- The Law of Charges:

Like charges repel, and unlike charges attract.

The Law of Charges:

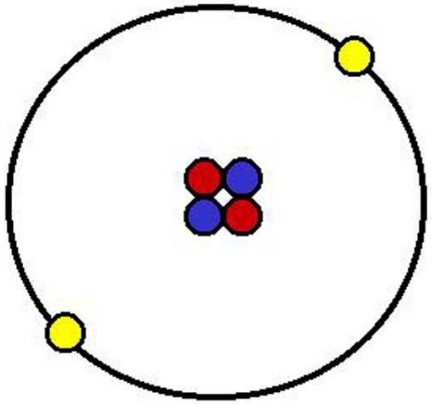


(a) A negatively charged rubber rod suspended by a thread is attracted to a positively charged glass rod. (b) A negatively charged rubber rod is repelled by another negatively charged rubber rod.

How do atoms become “charged?”

- Atoms become charged when they become more positive or more negative.
- How can this happen?

Remove or add a proton or an electron.

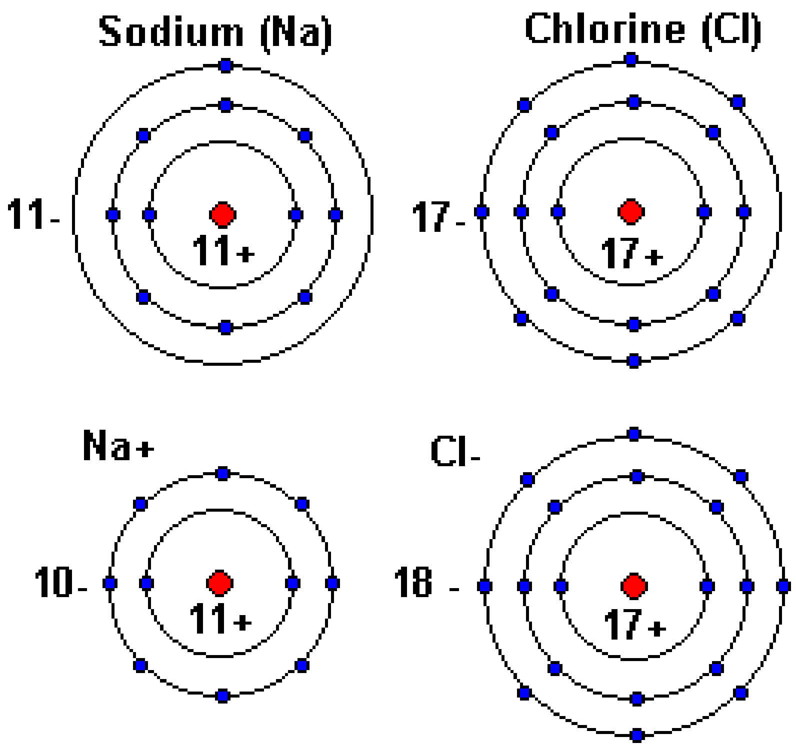


Protons and neutrons are bound together by the Strong Nuclear Force and it is very hard to separate them.

Electrons, however, can be more easily removed.

Ions

An atom with a deficiency of electrons is positively charged.



An atom with an excess of electrons is negatively charged.

ATOMS DO NOT GAIN OR LOSE PROTONS!!!!

Charge is a fundamental quality like mass.

- Charge is denoted as q.
- Charge has a fundamental unit of a Coulomb (C).
- Charges are usually really really small numbers (10^{-19}).
- So what is 1 C?
  - An object would have to have 6.25×10^{18} extra electrons to amount to –1 C of charge.
  - A lightning bolt is estimated to carry a charge of 10 C.
- Revisit the charges on an electron and proton.

Charges are quantized, can ONLY be in multiples of *e*

- Remember:
  - $-e$ = an electron = -1.60×10^{-19} C
  - $+e$ = a proton = $+1.60 \times 10^{-19}$ C
- An object that has a net charge of 8.0×10^{-19} C has a net charge of what multiple of e? Hint: How many electrons would need to be removed to create this charge?

The net charge would be +5e, 5 electrons were removed

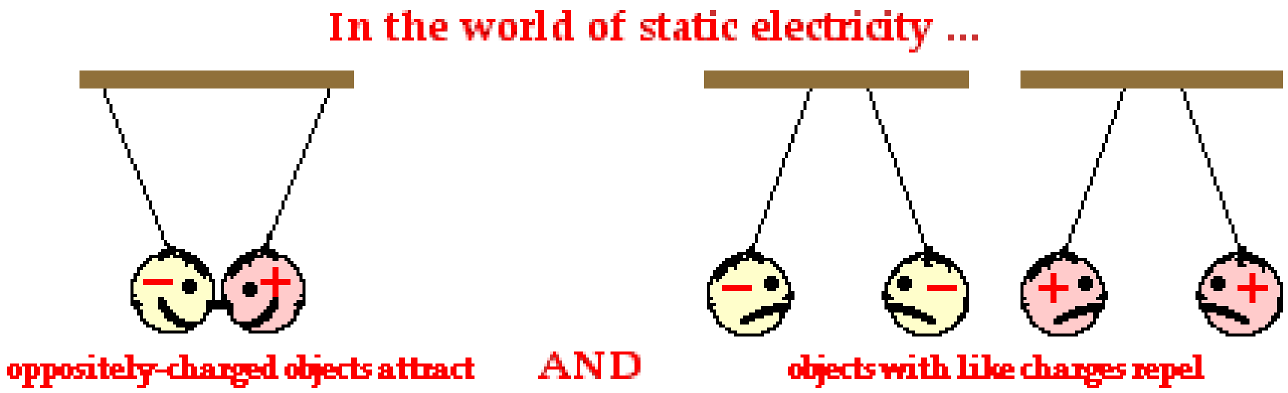
- Two kinds of charges occur in nature, with the property that unlike charges attract one another and like charges repel one another.
- Charge is conserved.
- Charge is quantized.

Multiples of Charges Chart

1e	1.6×10^{-19}
2e	3.2×10^{-19}
3e	4.8×10^{-19}
4e	6.4×10^{-19}
5e	8.0×10^{-19}

Electrostatic Force

- This is a non-contact force (like the gravitational force except instead of two masses exerting force on each other the two objects charges exert a force of repulsion or attraction).
- ANY charged object can exert the electrostatic force upon other objects- both charged and uncharged objects.



COULOMB'S LAW

Coulomb confirmed that the electric force between two small charged spheres is proportional to the inverse square of their separation distance

Coulomb's experiments showed that the **electric force** between two stationary charged particles

- is inversely proportional to the square of the separation r between the particles and directed along the line joining them;
- is proportional to the product of the charges q_1 and q_2 on the two particles;
- is attractive if the charges are of opposite sign and repulsive if the charges have the same sign.

From these observations, we can express **Coulomb's law** as an equation giving the magnitude of the electric force (sometimes called the *Coulomb force*) between two point charges:

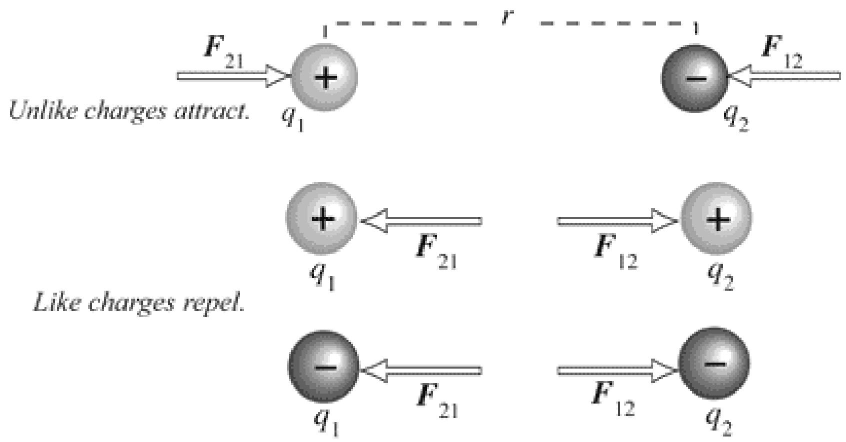
$$F_e = k_e \frac{|q_1||q_2|}{r^2}$$

where k_e is a constant called the **Coulomb constant.**

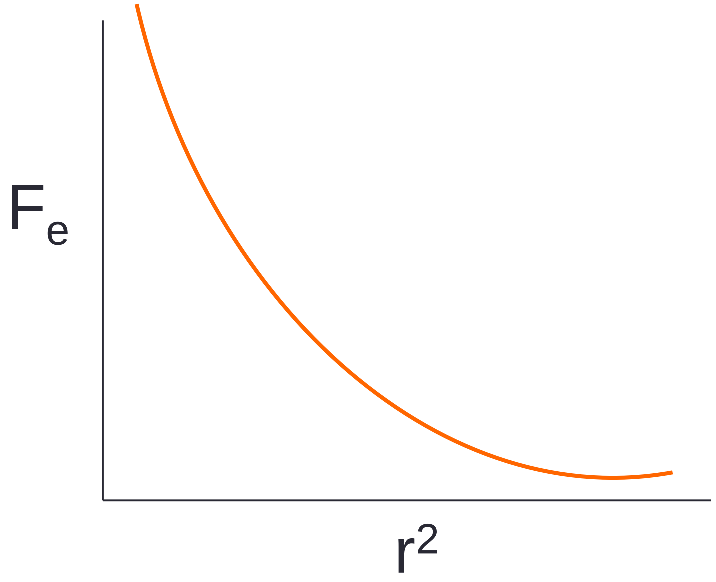
$$k_e = \frac{1}{4\pi\epsilon_0}$$

$$k_e = 8.987\,5 \times 10^9 \text{ N}\cdot\text{m}^2/\text{C}^2$$

The Electrostatic Force



$$F_e = k_e \frac{|q_1||q_2|}{r^2}$$



Example

The electron and proton of a hydrogen atom are separated (on the average) by a distance of approximately 5.3×10^{-11} m. Find the magnitudes of the electric force and the gravitational force between the two particles.

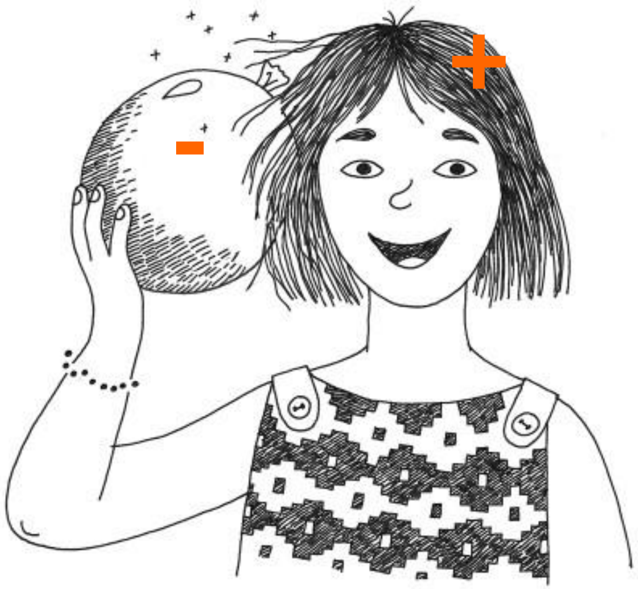
Solution From Coulomb's law, we find that the attractive electric force has the magnitude

$$F_e = k_e \frac{|e|^2}{r^2} = \left(8.99 \times 10^9 \frac{\text{N} \cdot \text{m}^2}{\text{C}^2}\right) \frac{(1.60 \times 10^{-19}\ \text{C})^2}{(5.3 \times 10^{-11}\ \text{m})^2}$$

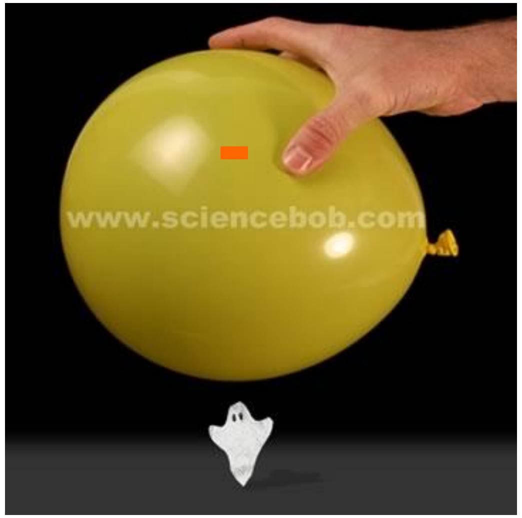
$$= \boxed{8.2 \times 10^{-8}\ \text{N}}$$

Example of Electrostatic forces

will have an ATTRACTIVE interaction with a neutral object.

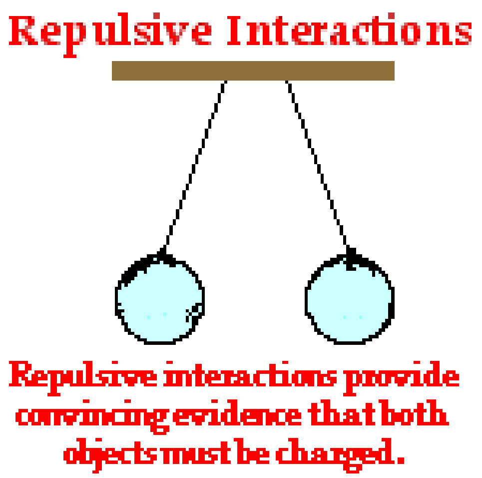


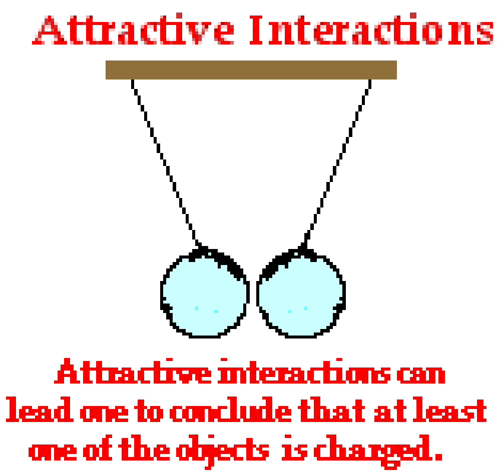
A balloon when rubbed on your head becomes charged by picking up extra electrons from your hair.



That same balloon, because it is charged, will attract a neutral object like pieces of paper.

So we are able to predict the charge on objects based on their interaction with other objects.





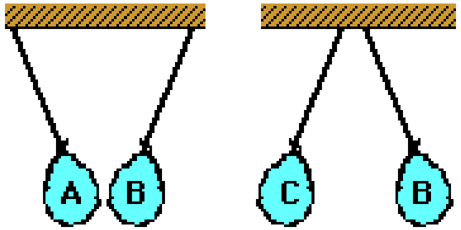
They can either both be positive or both be negative.

They can have opposite charges or one object is charged and the other is neutral.

Try this…

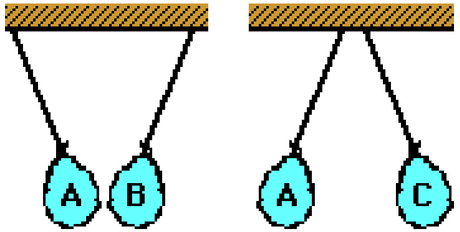
- On two occasions, the following charge interactions between balloons A, B and C are observed. In each case, it is known that balloon B is charged negatively. Based on these observations, what can you conclude about the charge on balloon A and C for each situation.

Case #1



Object	Conclusive evidence to conclude the charge is +, − , neutral
A	positive or neutral
B	negative
C	negative

Case #2

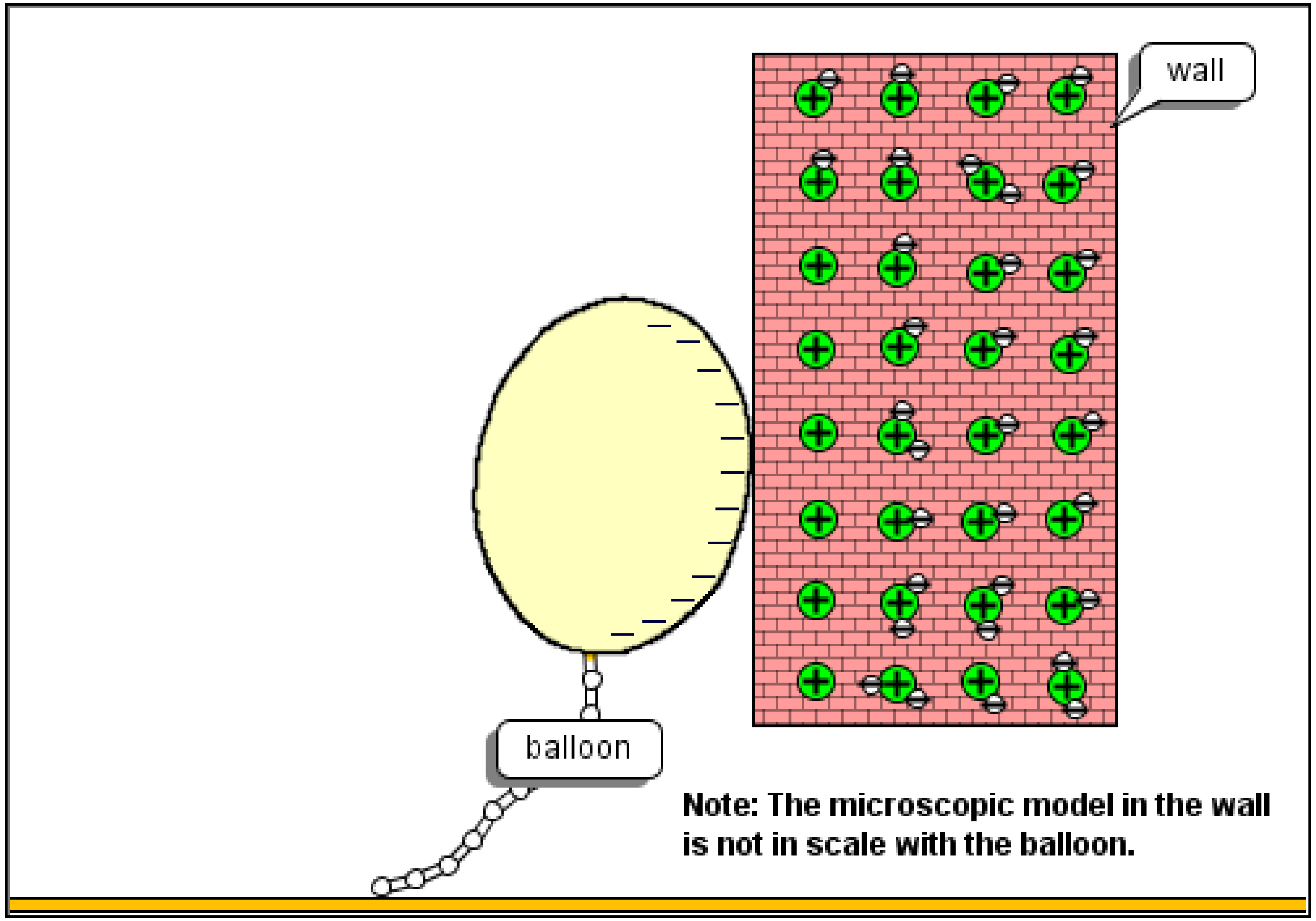


Object	Conclusive evidence to conclude the charge is +, − , neutral
A	positive (if it was neutral it wouldn’t repel C)
B	negative
C	positive

Why does the balloon stick to the wall?

- When a balloon is rubbed with a piece of cloth electrons are transferred between the two objects. Usually the balloon attracts extra electrons and then receives an overall negative charge.

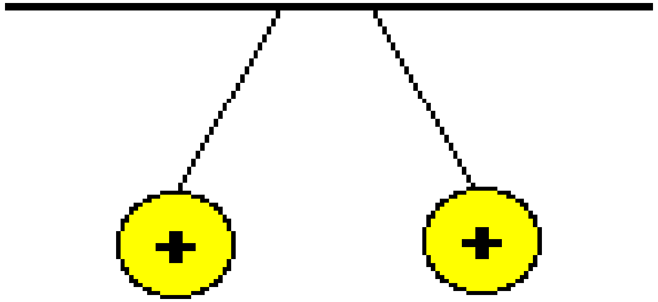
balloons static

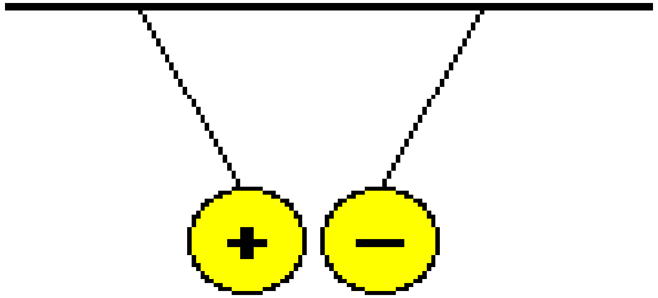


When the balloon is placed against the wall the excess electrons will repel the electrons in the wall and be attracted to the positive charges.

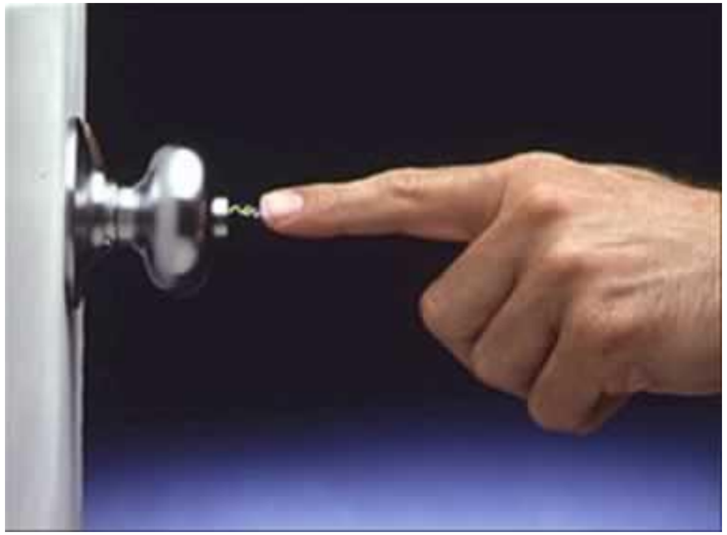
What happens to your hair when you rub a balloon on your head?

- The balloon, after being rubbed and then pulled away, removes some of the electrons in your hair which give each strand a positive charge. Like charges want to repel and each strand is repelling from the others and "sticking up."





Getting Shocked



- As you walk across a carpet, electrons are transferred from the rug to you.
- Now you have extra electrons.
- Touch a door knob (conductor) and ZAP!
- The electrons move from you to the knob.

Lightning

- Lightning is a REALLY big shock.
- Positive charges tend to go up, negative charges tend to go down.
- When the attraction reaches a critical level you get a lightning bolt.

Objects that tend to give up electrons and become positive:

- Glass
- Nylon
- Fur
- Hair
- Wool

Objects that tend to attract electrons and become negative:

- Rubber
- Polyester
- Styrofoam
- Saran Wrap
- PVC

Insulators and Conductors

- Different materials hold electrons differently.

- Insulators don’t let electrons move around within the material freely.
  - Ex. Cloth, Plastic, Glass, Dry Air, Wood, Rubber

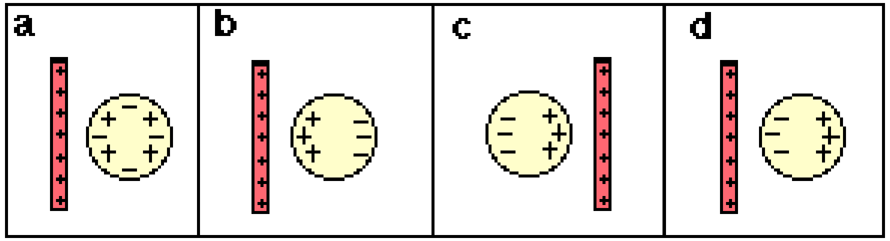
- Conductors do let electrons move around within the material freely.
  - Ex. Metals- Silver, Copper, Aluminum

Try this…

- A charged plastic rod is brought close a neutral metal sphere. How would the distribution of charges be in the metal sphere?

Try this…

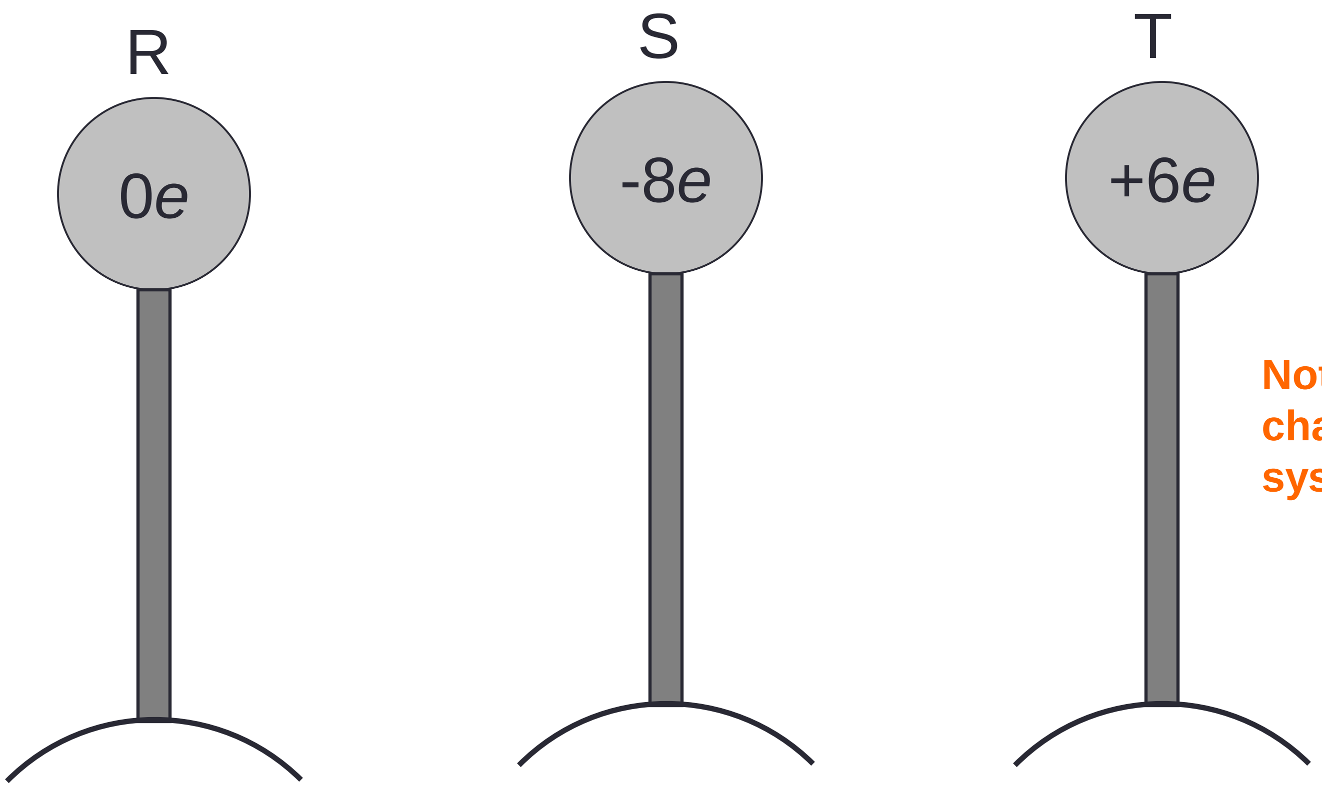
- Which of the diagrams below best represents the charge distribution on a metal sphere when a positively charged plastic tube is placed nearby?



Law of Conservation of Charge

- Charges within a closed system may be transferred from one object to another, but charge is neither created nor destroyed.

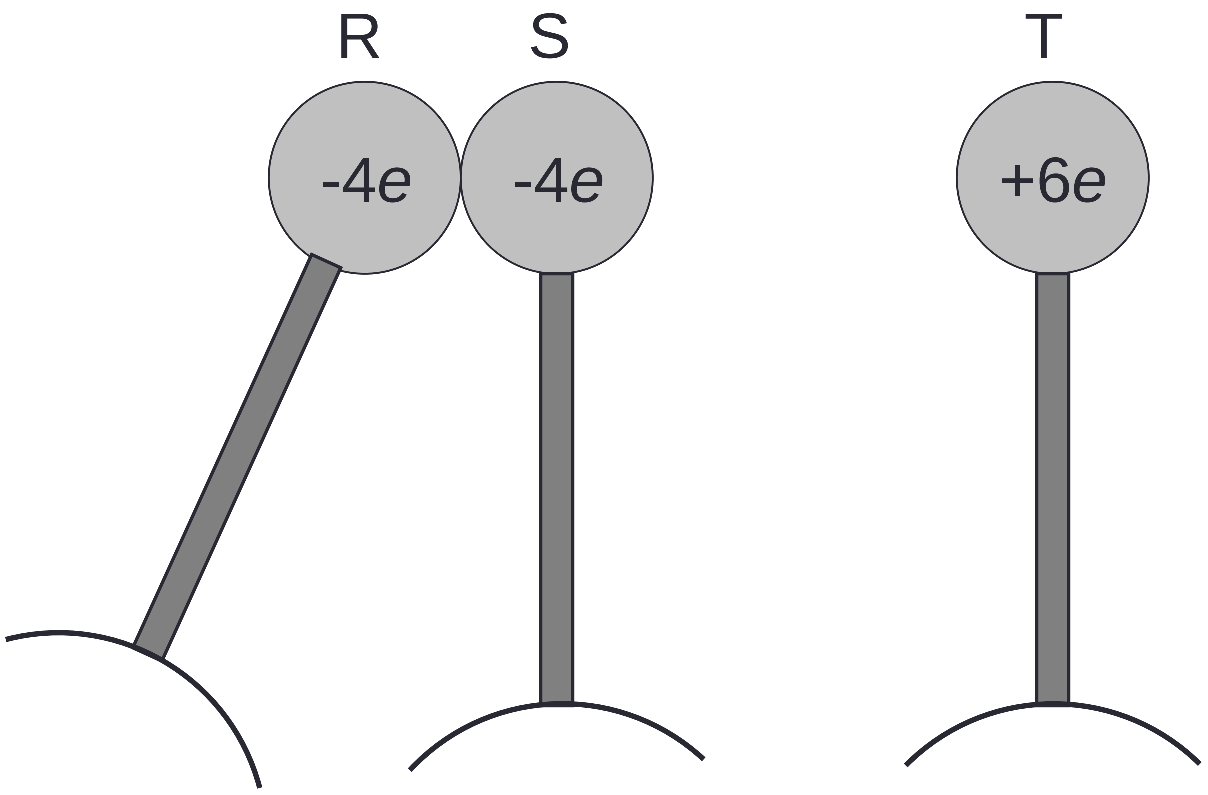
The diagram below shows the initial charges and positions of three metal spheres, R, S, and T, on insulating stands.

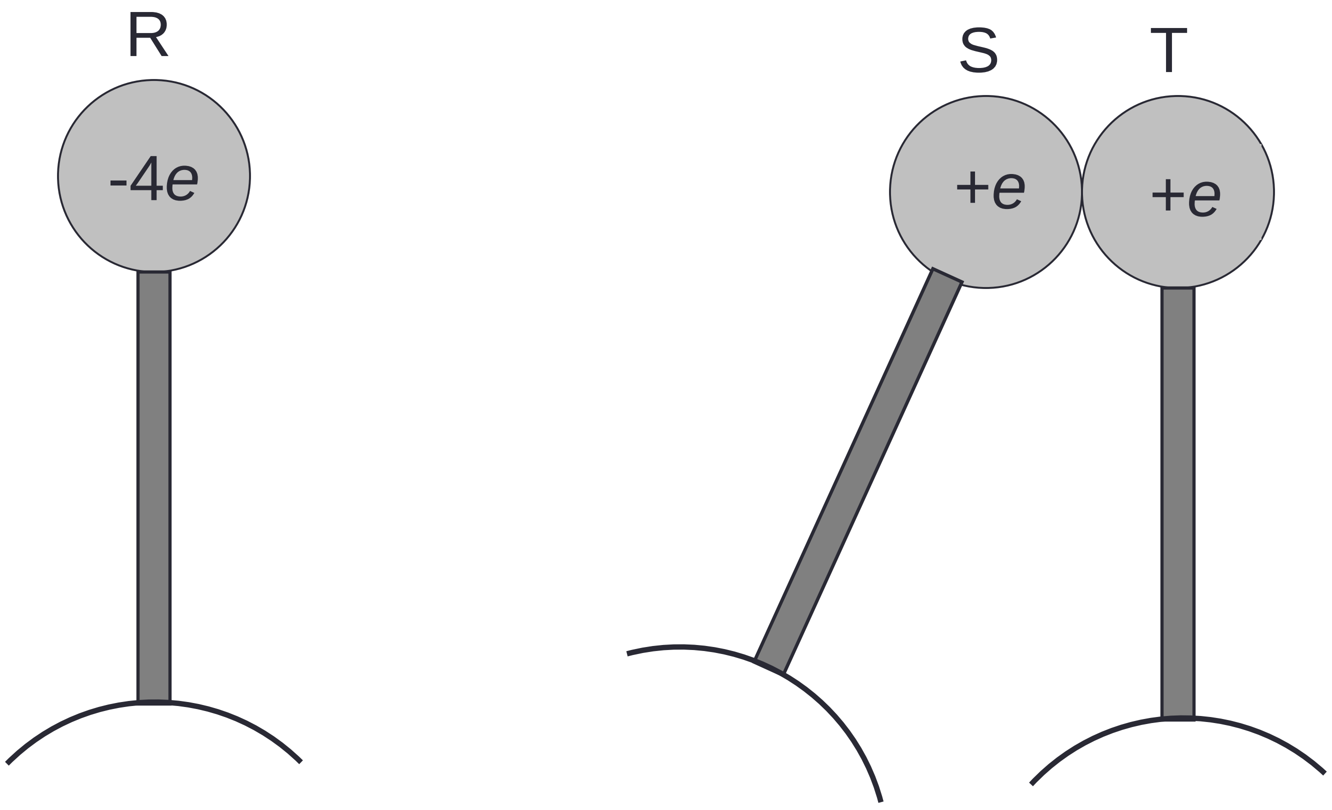


Note that the net charge of the system is -2*e*.

Sphere R is brought into contact with sphere S and then removed. Then sphere S is brought into contact with sphere T and removed. What is the charge on sphere T after this procedure is completed?

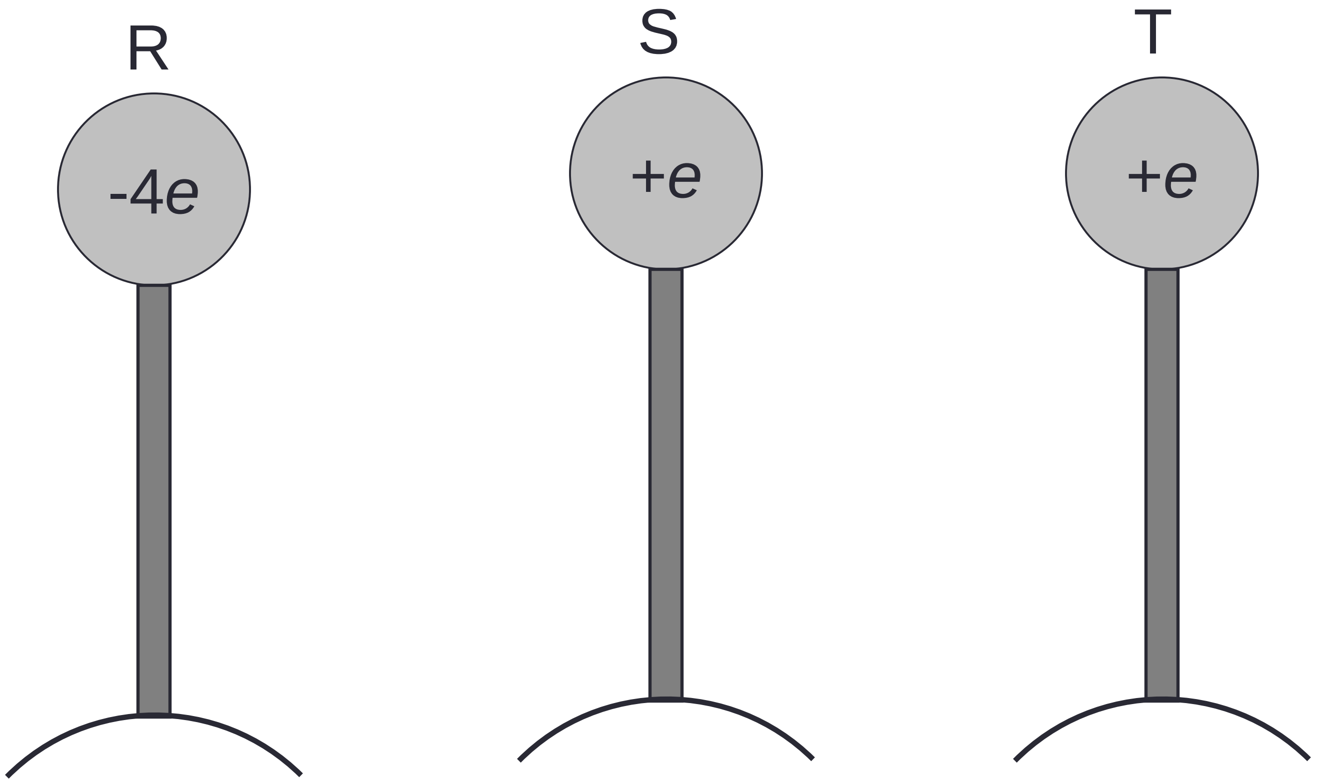
When the spheres come in contact the charge will be distributed evenly between both spheres.





$$\frac{-4e + 6e}{2} = \frac{+2e}{2} = +e$$

Note that the charge of the system is conserved- the initial charge is the same as the final charge.

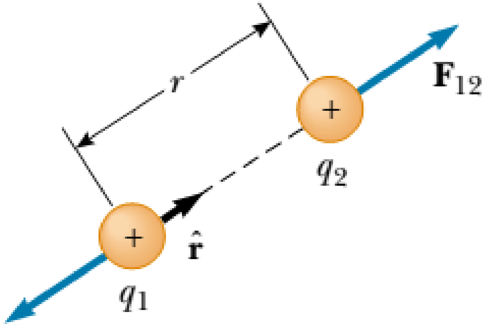


$-4e \quad + \quad e \quad + \quad e \quad = -2e$

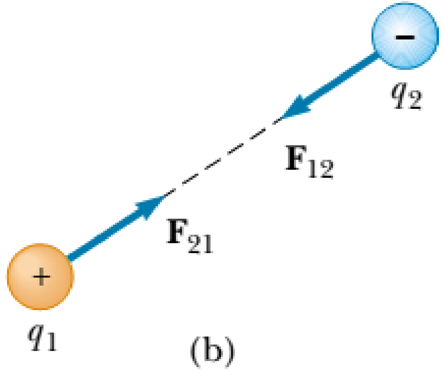
Electrostatic force is a vector quantity

Thus, the Coulomb's law expressed in vector form for the electric force exerted by a charge $q1$ on a second charge $q2$, written F_{12}, is

where $\hat{\mathbf{r}}$ is a unit vector directed from q_1 to q_2



(a)



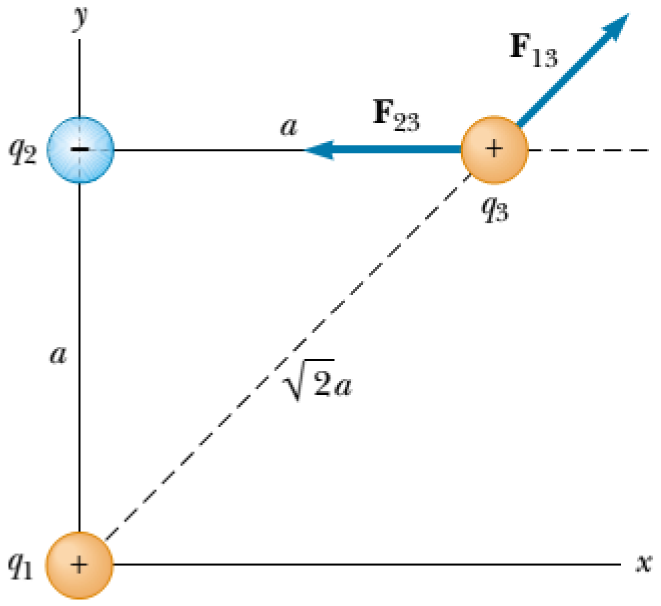
(b)

Because the electric force obeys Newton’s third law, the electric force exerted by q2 on q1 is equal in magnitude to the force exerted by q1 on q2 and in the opposite direction; that is,

$$\mathbf{F}_{21} = -\mathbf{F}_{12}$$

Example

Consider three point charges located at the corners of a right triangle as shown in Figure 23.7, where $q_1 = q_3 = 5.0\ \mu C$, $q_2 = -2.0\ \mu C$, and $a = 0.10$ m. Find the resultant force exerted on q_3.



Solution First, note the direction of the individual forces exerted by q_1 and q_2 on q_3. The force F_{23} exerted by q_2 on q_3 is attractive because q_2 and q_3 have opposite signs. The force F_{13} exerted by q_1 on q_3 is repulsive because both charges are positive.

The magnitude of $\mathbf{F}_{23}$ is

$$F_{23} = k_e \frac{|q_2||q_3|}{a^2}$$
$$= \left(8.99 \times 10^9\ \frac{\mathrm{N \cdot m^2}}{\mathrm{C^2}}\right) \frac{(2.0 \times 10^{-6}\ \mathrm{C})(5.0 \times 10^{-6}\ \mathrm{C})}{(0.10\ \mathrm{m})^2}$$
$$= 9.0\ \mathrm{N}$$

The magnitude of the force exerted by q_1 on q_3 is

$$F_{13} = k_e \frac{|q_1||q_3|}{(\sqrt{2}a)^2}$$

$$= \left(8.99 \times 10^9 \frac{\mathrm{N \cdot m^2}}{\mathrm{C^2}}\right) \frac{(5.0 \times 10^{-6}\ \mathrm{C})(5.0 \times 10^{-6}\ \mathrm{C})}{2(0.10\ \mathrm{m})^2}$$

$$= 11\ \mathrm{N}$$

The force $\mathbf{F}_{13}$ is repulsive and makes an angle of 45° with the x axis. Therefore, the x and y components of $\mathbf{F}_{13}$ are equal, with magnitude given by $F_{13} \cos 45° = 7.9$ N.

The force $\mathbf{F}_{23}$ is in the negative x direction. Hence, the x and y components of the resultant force acting on q_3 are

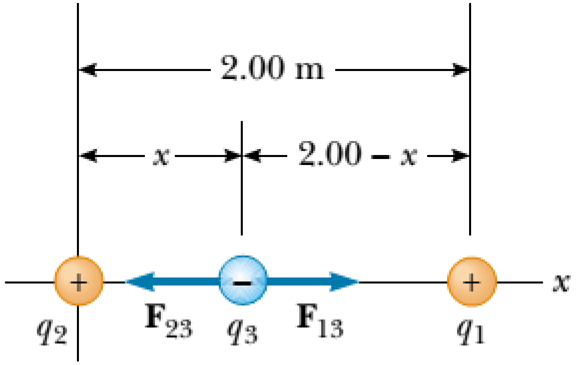
$$F_{3x} = F_{13x} + F_{23} = 7.9\ \mathrm{N} - 9.0\ \mathrm{N} = -1.1\ \mathrm{N}$$

$$F_{3y} = F_{13y} = 7.9\ \mathrm{N}$$

We can also express the resultant force acting on q_3 in unit-vector form as

$$\mathbf{F}_3 = (-1.1\mathbf{i} + 7.9\mathbf{j})\ \mathrm{N}$$

Example



Three point charges lie along the x axis as shown in Figure 23.8. The positive charge $q_1 = 15.0\ \mu C$ is at $x = 2.00$ m, the positive charge $q_2 = 6.00\ \mu C$ is at the origin, and the resultant force acting on q_3 is zero. What is the x coordinate of q_3?

Solution Because q_3 is negative and q_1 and q_2 are positive, the forces $\mathbf{F}_{13}$ and $\mathbf{F}_{23}$ are both attractive, as indicated in Figure 23.8. From Coulomb's law, $\mathbf{F}_{13}$ and $\mathbf{F}_{23}$ have magnitudes

$$F_{13} = k_e \frac{|q_1||q_3|}{(2.00 - x)^2} \qquad F_{23} = k_e \frac{|q_2||q_3|}{x^2}$$

For the resultant force on q_3 to be zero, $\mathbf{F}_{23}$ must be equal in magnitude and opposite in direction to $\mathbf{F}_{13}$, or

$$k_e \frac{|q_2||q_3|}{x^2} = k_e \frac{|q_1||q_3|}{(2.00 - x)^2}$$

Noting that k_e and q_3 are common to both sides and so can be dropped, we solve for x and find that

$$(2.00 - x)^2|q_2| = x^2|q_1|$$

$$(4.00 - 4.00x + x^2)(6.00 \times 10^{-6}\ \text{C}) = x^2(15.0 \times 10^{-6}\ \text{C})$$

Solving this quadratic equation for x, we find that $x = 0.775$ m. Why is the negative root not acceptable?

Example

Two identical small charged spheres, each having a mass of 3.0×10^{-2} kg, hang in equilibrium as shown in Figure 23.9a. The length of each string is 0.15 m, and the angle θ is 5.0°. Find the magnitude of the charge on each sphere.

Solution From the right triangle shown in Figure we see that $\sin\theta = a/L$. Therefore,

$$a = L\sin\theta = (0.15\text{ m})\sin 5.0° = 0.013\text{ m}$$

The separation of the spheres is $2a = 0.026$ m.

The forces acting on the left sphere are shown in Figure Because the sphere is in equilibrium, the forces in the horizontal and vertical directions must separately add up to zero:

$$(1) \qquad \sum F_x = T\sin\theta - F_e = 0$$

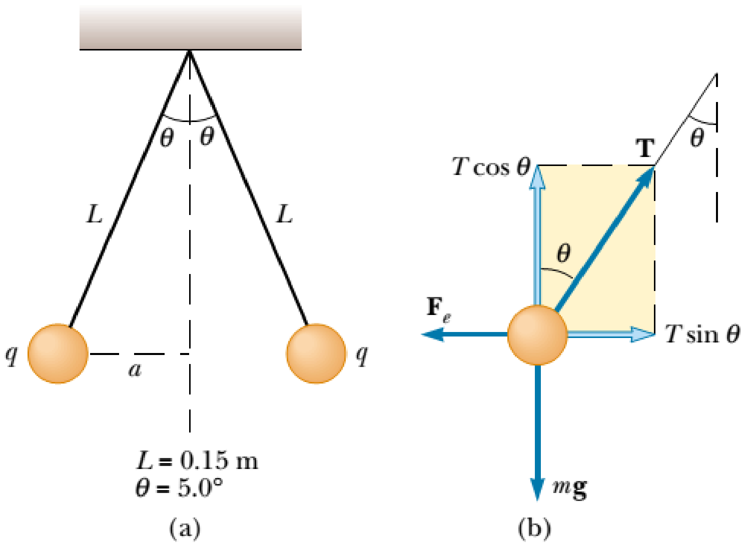
$$(2) \qquad \sum F_y = T\cos\theta - mg = 0$$

From Equation (2), we see that $T = mg/\cos\theta$; thus, T can be eliminated from Equation (1) if we make this substitution. This gives a value for the magnitude of the electric force F_e:

$$(3) \qquad F_e = mg\tan\theta$$

$$= (3.0 \times 10^{-2}\text{ kg})(9.80\text{ m/s}^2)\tan 5.0°$$

$$= 2.6 \times 10^{-2}\text{ N}$$



$$F_e = k_e \frac{|q|^2}{r^2}$$

where $r = 2a = 0.026$ m and $|q|$ is the magnitude of the charge on each sphere. (Note that the term $|q|^2$ arises here because the charge is the same on both spheres.) This equation can be solved for $|q|^2$ to give

$$|q|^2 = \frac{F_e r^2}{k_e} = \frac{(2.6 \times 10^{-2}\ \mathrm{N})(0.026\ \mathrm{m})^2}{8.99 \times 10^9\ \mathrm{N \cdot m^2/C^2}}$$

$$|q| = \boxed{4.4 \times 10^{-8}\ \mathrm{C}}$$

Exercise If the charge on the spheres were negative, how many electrons would have to be added to them to yield a net charge of -4.4×10^{-8} C?

Answer 2.7×10^{11} electrons.